A Novel Interaction System with Force Feedback between Real - and Virtual Human

An Entertainment System: “Virtual Catch Ball"

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ABSTRACT

In the existed studies, interaction system involving force and touch feedback, have been scarely suggested any research. Therefore, we focus on touch and force-feedback activities in interaction with real human. In this paper, we propose the interaction system which combines an immersive virtual environment with human-scale haptic interface. And we implement *reactive virtual human* that user can visual- and force feedback. With the implemeted system, we developed *Virtual Catch Ball* system. Through this experience, we confirmed that our system have the potential to succeed for a novel communication channel. We desire that our approach can be utilized in creating a more natural and intuitive interaction.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interface—*Haptic I/O*; I.3.6 [**Computer Graphics**]: Methodology and Techniques—*Interaction Techniques*; I.3.7 [**Computer Graphics**]: Three-dimensional Graphics and Realism—*Virtual Reality*

Keywords

Virtual Human, Force Feedback, Reactive Motion, Multimodal Interaction

1. INTRODUCTION

Recently, as great progress of CG technologies, realistic-looking virtual humans have been simulated in any virtual scene that re-create real world. Moreover, the virtual human's behavior acts on the premise of knowledge-based perception and intelligence such as understanding a natural language and speaking with a adequate facial expression and gesture. Although these are effective communication channels in most interaction, they are not enough to make us fully engaged in a interaction. In an actual world, there are a immediacy and intimacy unparalleled by words and images. A communication between people can be generated and understood by nonlogical information such as sensibility and reflex movements that aren't controlled by knowledge-based and logical information[12]. In particular, the non-logical layer which involves touch and force feedback goes smoother communication between people. For instance a handshake, an encouraging part on the back, all of them speak to a profound expression of physical contacts. These factors make user's presence enhance and thus keep our interest in the interaction to a larger extend. However, in the existing studies, the interaction with real human, haven't been involved senses of different style such as touch and force sensation. It is caused, in most cases, by bottleneck in realization of a life-size haptic interface.

Therefore, our studies focus on force interfaces involving intuitive feelings and strong sense of feedback. In this paper, we propose the human-scale virtual environment with haptic elements and the reactive virtual human that is capable of visual and haptic representation. With the system, user can interact with virtual human that generate his reaction according to physical input originated by user's action. By transmitting the feedback force to user's partial body, user feels a strong link about virtual human in VE. Based on this concepts, we describe the *Virtual Catch Ball* system that can do force feedback interaction between a real- and virtual human. Through this experience, we will confirm our approach is effective in a more natural and direct interaction with VE.

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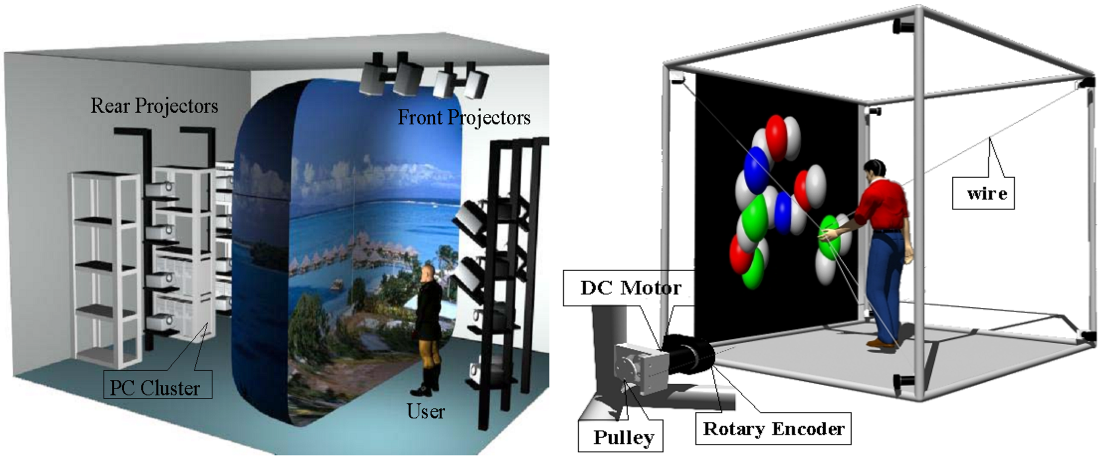
2. RELATED WORKS

Many applications already utilize human senses and provide rich experiences in VE. However interaction involving force and touch, have been scarely suggested any research. In this section, we look at applications whose aims are relatively similar to ours. This includes research that focus on interaction using various input devices integrating force and touch.

Firstly, it is interesting to note that researches utilize users's body movements to interact with the virtual environment. The Virku research project [10][11] has developed *bodily user interfaces* that integrate an exercise bicycle or



(a) A large scale multi-projector display(D-Vision).

(b) A human-scale haptic interface(Spidar-H)

Figure 1: The framework of interaction system with high-immersive display and haptic interface.

floor sensors and an immersive display system for increasing motivation during workout sessions. We entirely agree that computer interfaces should allow the user to control the interaction using his whole body. Benoir et al. [2] has built a virtual training environment for various purposes based on a motion capture system incorporating visual feedback. Because existing interactions does not include haptic interface, they are subject to the problem of diminishing user activeness and interest as was mentioned in the introduction. When the current interfaces are supplemented by force - and touch feedback, the user can benefit from a more profound interaction and a stronger sense of presence of the virtual human.

Cai[4] et al. realized force feedback using a string-based haptic interface in a human-scale VE. There are a good attractive aspects that the additional information from haptic feedback, such as force, weight, or other physical properties bring the benefits to the immersive environment, and user can operate objects in a natural manner. Fischer et al.[5] combined the haptic device with a six-sided projection screen virtual environment. However, these proposal have been focused on only intercation with objects and are apt to make weaker link between user and interaction objects. Otherwise, we create a new communication channel through force feedback interaction with life-like virtual human unlike other haptic interfaces.

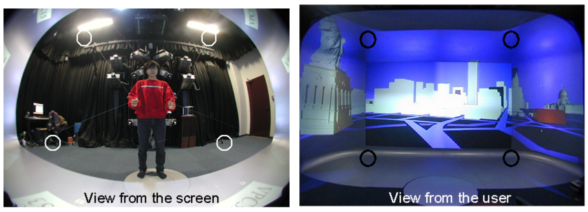


Figure 2: A snapshot of the implemented system; Circles depict positions of the motor is placed in the system.

3. SYSTEM ORGANIZATION

3.1 Basic Components

For creating the force feedback interaction with real human, the system should first of all, give feedback to the user's body in an immediate fashion. It should also represent the virtual human's reactions in a human-scale environment. Secondly, an immersive sensation or presence are an important element when user steps into the virtual world. The sense of presence makes the user feel that they are actually visiting and being part of the virtual environment. The system should allow the user to move freely and easily and to feel and manipulate virtual objects with his body so as to create an intuitive interface. At last, virtual human should be life-size. His movements require real and natural styles according to user's action. All of three components are essential elements for the desirable interaction system. These should also integrate well.

3.2 Human-scale Virtual Environment with Haptic Interface

To satisfy these criteria, we adopted to use a large scale immersive system which enable to the use of multiple senses; the wire driven force feedback SPIDAR-H[3] system and a multi-projector display system(D-vision) [9]. This system represents a real virtual human's movement in a large-scale display using a motion database while the user performs actions in real time. In addition to the visual representation, the force feedback interface produces intuitive interaction between the real- and virtual world. As shown in Figure 1 (a), the display system covers the field of vision completely with 180 °of viewing angle and can produce stereoscopic images. High-quality(4608x3584 pixels) images displayed by the projectors are generated by 24 PCs that are interconnected by a 2.0 Gbps network. An UDP-based network application synchronizes each frame of the display. This environment provides a work space($4 \times 6.3 \times 1.5\ m^3$) where user can move around.

In the immersive virtual environment, the haptic interface, SPIDAR-H driven by some motors and strings is developed. The device is based on a haptic interface SPIDAR for desktop operation. Figure 1 (b) shows a framework of the SPIDAR-H interface. We contrived the installation of haptic device on the display for attaining user's natural manner. In this system, total 8 motors for both hands are placed as surrounding the user. As shown in Figure 2, motors set up behind the screen and behind the user, drives the wires. One end of wire is wrapped around a pulley driven by a DC motor and the other is connected to the user's finger. By controlling the tension and length of each wire, the SPIDAR-H generates an appropriate force using four wires connected to the ring-type clip put on the user's finger. Because it is a wire-based system, it has a transparent property so that the user can easily see the virtual world. It also provides a space where the user can freely move around. The wires are soft, so there is no risk of the user hurting himself if he would get entangled in the wires. The human-scale haptic device allows the user to manipulate virtual objects during his action, and when the user acts in to convey the sense of force to the user's body naturally.

When a user manipulates virtual objects through this system, haptic- and physical information is conveyed from the real world to the virtual one. The information originating from the user becomes key factors when generating the virtual human's reactions.

3.3 Reactive Motion Generation

There are two basic ways to animate a virtual human; to use motion capture and a computational approach such as kinematics and dynamics techniques. Kinematics is generally better for goal-directed activities, and slower controlled action. Dynamics is more natural for movements directed by application of forces, impacts and high-speed behaviors[7]. However, at present the latter is of limited use because of too high a computational cost when trying to describe naturally looking motion in real-time. Otherwise, motion-capture based techniques are the easiest way to produce naturally looking animations [1] today. To generate realistic and individual motion of life-size virtual human, we use a wireless magnetic motion capture system.

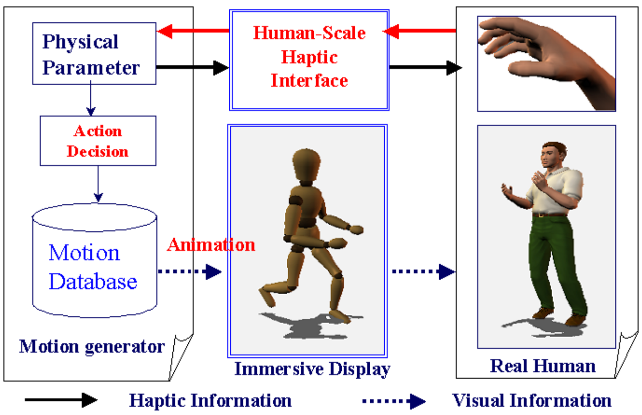


Figure 3: The basic concept for interaction system with force feedback.

In our system we designed a database containing the required motion. To build this database, we first captured real humans's interaction movements under various situations. Then we classified the motions according to categories of primitive actions and converted the action data to fit our motion database. The motion information is recorded in each the defined table. The primitive motion tables include various kind of actions such as pick-up and walk and reactive motions intuitively responds to the user's action. For example, the virtual human performs a *catch the ball*-movement when a user throws a ball. We compute the instant of the virtual human's catch using physical parameters such as the ball direction and speed. The key-frame information record in the parameter table.

We access and alter the contents of database through the Open Database Connectivity API. The input parameters from the haptic interface are used in the execution of a series of statements that produce a resultant motion. When the specified conditions are met, the matched motion series are returned to the calling server environment. The server share and send motion data to a group of rendering nodes using broadcast messages.

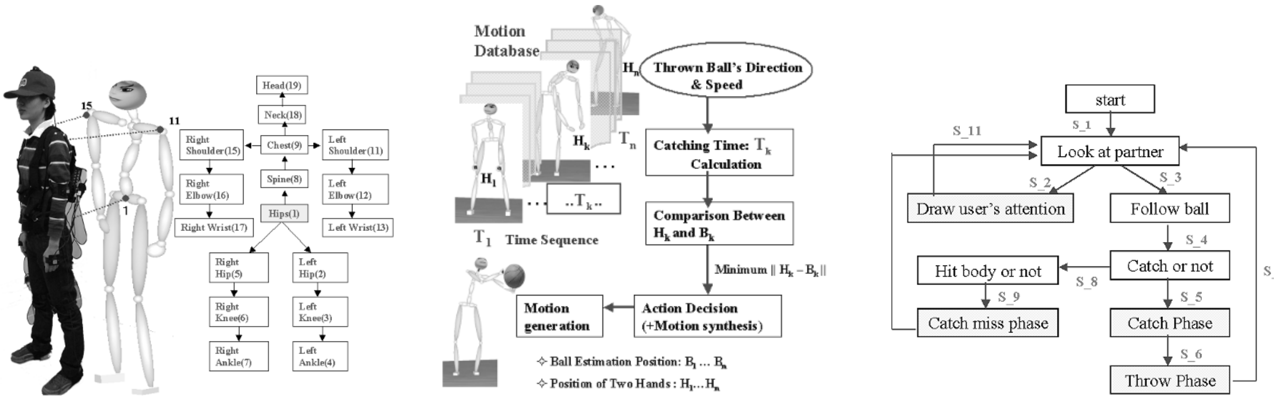
Figure 3 shows the basic concept that generate virtual human's reactive motion through motion database and human-scale haptic interface. When a user interacts with virtual human, the physical information of the user input by haptic interface is analyzed by a motion generator part, and it decides what kind of reactive motion do virtual human. The part retrieves the data that cope with motion database. Then those animate in accordance with time and physcial space on a human-scale display, and at the same time, transmit an appropriate force to user.

4. AN ENTERTAINMENT SYSTEM: "VIRTUAL CATCH BALL"

As an example of our proposed system, we developed *Virtual Catch Ball*. In this game, there is an implicit understanding of the situation between the two players. Even if the principle of catch ball is very simple it requires elaborate observations of the partner's actions and the user instinctively judge speed and ball trajectory with reference to his body. The user will notice that it can perform naturally reactive movements of catching a ball according to the thrown ball's position and direction.

4.1 Implementation

We adopt a simple skeleton model that can perform real movements adequately in real time. The model is composed of 19 joints as shown in left of Figure4 (a) and it has a hierarchical structure. The root is represented by position and angle. The other joints are represented only by a relative angle. Because each joint is defined by a coordinate relative the root the world coordinates of end-effectors are calculated by synthesizing the components of the hierarchical structure starting from the root. This conversion is needed for the collision detection between the hand end-effectors and virtual objects since the latter is expressed in world coordinates. At the instant of catch, we use the motion data with the minimum distance between the ball and the hands' position to find the best-fit motion. The matched motion maps to the data structure of the skeleton model. Lastly, reactive motions are generated through a motion synthesis process



(a) Hierachy of the skeleton model.

(b) Motion Retrieving Process.

(c) Motion control flow diagram.

Figure 4: Construction for Reactive Motion Generation.

consisting of choosing catch, hold, throw and "I'm ready"-movements. Figure 4(b) shows the retrieve process in more detail.

If the user deteches his two hands from the ball at once and the ball exceeds a defined speed limit (2 m/s), we suppose that the user wants to throw the ball. After release, the ball moves in the virtual space in accordance with the basic laws of physics. The virtual human catches the ball using physical parameters estimated from information supplied by SPIDAR-H. Using the SPIDAR-H device of our proposed system, the user can hold and throw the virtual ball like a real one. In this system, the user can rotate and move the ball like in the real world because the virtual ball's physical movement and forces are generated according to the direction and force exerted by the user. As shown in Figure4(c), when the virtual human sees the approaching ball it goes through transition s_4 into the state **catch or not**. If the ball is estimated to come close enough to the virtual human's hand, in other words it has found a matching key-frame data in the motion database, it changes to the state **catch**(s_5) or **catch miss**(s_9) according to its decision. When it enters into the state **catch phase**, the virtual human decides the throw direction so as to reach the user's hands. If the ball collides with some other part of the virtual human's body before it reaches its hands the ball will fall onto the ground. According to the collision point it is decided if it is a catch miss movement. After the **throw phase** or **catch miss phase** state, the virtual human enters the following state and a new cycle begins. As shown in (a) of Figure 5, the user grabs and handling the ball using his hands by interacting with the haptic interface. The virtual human's catch- and throw motions are depicted by 4 frame of Figure 6.

4.2 Evalution & Discussion

The interaction system, *Virtual Catch Ball* has been experienced by people participated during public open. Although the game involves an interaction only through a ball, we could confirm that most people who used the system, found lasting interest in the interaction. This shows us that interaction using force feedback has a positive effect when trying

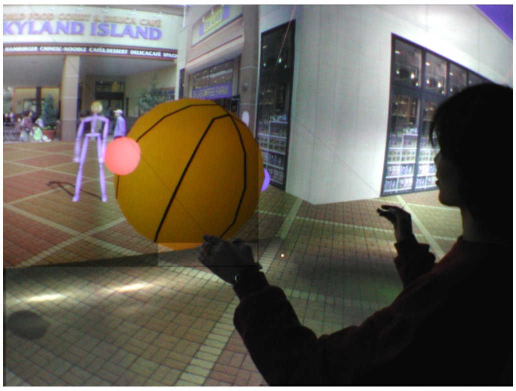


Figure 5: A user handling a virtual ball using SPIDAR-H device.

to generate life-like presence of a virtual human. In order to survey participants' impression influenced by the reactive virtual human, we carried out end-user evalution through subjective analysis. The questionnaire adopts a seven-point scale format that is based on the semantic differential principle[8]. A total of 10 person(8 men and 2 women) served as participants. The experiment requires user to perform "Catching Ball" game with virtual human of 3-type pattern from simple A to various motion C using haptic interface. After each set of playing the game, participants fill out the degree of his feeling with nature, reactivity and interest factor against the experiment. At the result, all factors correlated significantly with virtual human's motion pattern. The more various motion patterns, the better user's impression. Figure 7 shows the means of evalution value in each factor.

However, this is just the beginning in creating a new kind of interaction using force feedback which involves not only the user's body movement but also haptic feedback of the virtual partner's actions. The haptic feedback interface does leave a gap between the real- and virtual world due to the use of a single point of contact as a substitute for palm of the

Figure 6: A demonstration of "Virtual Catch Ball"; (1)user throws the ball (2)virtual human catches the ball (3) virtual human returns the ball to user (4)user starts to catch the ball

hand. We will continue to do improvements to our system such as increasing the comfort and adding other physical phenomena such as weight and air resistance (drag).

The people who used the system pointed out inconsistencies in the animation of the virtual human leading to unnaturally looking behavior. This problem mainly occurs while switching from one state to another such as when waving its arms to get the user's attention after throwing the ball. The motion interpolation problems are not unique to motion capture and will arise in motion created with other methods such as key-frame animation and physical simulation as well [6]. Much of the recent research[14][13] has been directed towards editing and reuse of existing motion data. Besides resolving the issues, we should seek a more better way to keep a balance between real-time motion synthesis and realistic human motions.

5. CONCLUSIONS

In this paper, we proposed a interaction system that combines a force feedback device and a human-scale virtual environment. And we realized *reactive virtual human* that can do visual- and force feedback with user. With the implemeted system, we developed *Virtual Catch Ball* system with force interaction like real world. Through this experience, we could confirm the potential of this system as a framework of natural and intuitive interaction. In the near future, we will build a more believable multi-modal interaction system that involves other senses such as gaze and tactile sensation. Moreover, we will begin to create a touchable virtual human.

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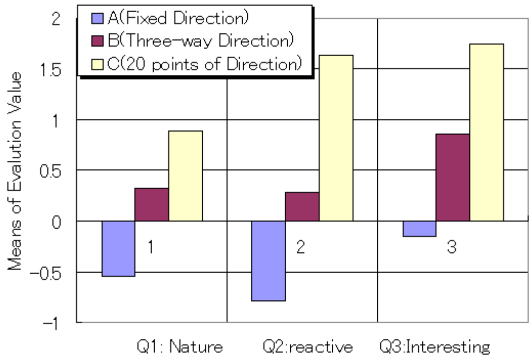

Figure 7: Means of evaluation value about three factors

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